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CHAPTER 6 -- EXAMINATION PROCEDURES, PART I: PRETEST DETERMINATIONS, INSPECTION

OBJECTIVES

After studying this chapter, and reviewing its contents with your instructor, you will be able to:

1. Describe the components of an official field examination.

2. Understand the organization and use of the Examination Procedure Outline (EPO) for loading-rack meters.

3. Describe the Pretest Determinations set forth in the EPO for loading-rack meters.

4. Describe the function of the National Type Evaluation Program (NTEP), and the use of NTEP evaluations in preparing to examine a specific device.

5. Identify the specific elements of a loading-rack metering system that are subject to inspection in the course of an official field examination.

6. Understand the specifications and other requirements established in NIST Handbook 44 that are relevant to inspection procedures.

7. Describe specific procedures for inspecting loading-rack metering systems in the field.

THE EXAMINATION PROCEDURE OUTLINE

What you have learned about the role of loading-rack metering systems in the commercial marketplace should help you appreciate the importance of your jurisdiction's program of regular field examinations for metering systems currently in service. Similarly, the basic knowledge you have acquired about the design and operation of these sophisticated liquid-measuring devices should make it obvious that systematic procedures must be employed for inspecting and testing them.

Given the complexity of the loading-rack metering system and the number of individual components that must function correctly to provide accurate and consistent measurement, a haphazard approach would at best be inefficient, requiring excessive time and effort to achieve complete and significant results, and thereby diminishing the overall effectiveness of the program. At worst, a haphazard approach could lead to overlooking or misinterpreting significant data, thereby compromising -- even invalidating -- the entire examination. In this chapter and those that follow you will receive a thorough introduction to examination procedures that employ a systematic approach to inspection and testing in the field.

The purpose of an official weights and measures examination is to determine whether the device being examined meets requirements that are established by law, or by legally mandated regulations. Thus, legal requirements form the basis of all examination procedures, and a thorough knowledge of applicable codes and administrative policies is as important a part of the inspector's job as knowing how to set up and use a field standard prover or how to conduct a slow-flow test.

Most jurisdictions have adopted the comprehensive specifications, tolerances, and other technical requirements set forth in NIST Handbook 44. The requirements that apply to loading-rack metering devices are included in Sections 1.10 (General Code) and 3.30 (Liquid-Measuring Devices Code) of the handbook. These codes will be referenced throughout the following discussions. Some jurisdictions have modified portions of these codes,

and in some jurisdictions additional requirements have been established by State and/or local laws and regulations. Your instructor will point out specific differences between Handbook 44 and the applicable codes in force in your jurisdiction and explain the significance of these differences.

Codes provide the basis for field procedures, but they are organized in a way that suits their primary function as legal documents, and as a result are often not very well suited to use in the field. Specific requirements that govern a particular component or feature of the metering system sometimes appear at separate places in the codes, and some requirements are applicable to more than one element of the system. In recognition of the need for a more systematic organization of requirements, one that is suited to efficient field procedures, the Office of Weights and Measures at the National Institute of Standards and Technology has developed Examination Procedure Outlines (EPO's) for many weighing and measuring devices, including loading-rack metering systems.

Figure 6-1 reproduces a sample page from the EPO for loading-rack meters. As you can see, the EPO provides a systematic organization, in this case grouping specifications and requirements from both the General and LMD Codes under headings that correspond to the order in which the Inspection can most efficiently be conducted. Notice that the right-hand column cites the applicable paragraphs of the Handbook 44 codes that mandate or specify these items, and that the effective year of nonretroactive requirements is given.

EPO No. 25

Pretest Determinations (cont.):

6. Prover sight glass must be clean and fittings must not leak.

7. Available test fluid must be of the same general physical characteristics as that of the liquid to be commercially measured by the device. N.1.1.

8. For top loading provers, the prover inlet must be lower than the outlet of the meter discharge line.

9. Determine applicable tolerance values:
   Applicable requirements . . . . . G-T, T.1.
   Basic values . . . . . T.2.3.2.
   a. On normal tests:
      Acceptance tolerance 0.2%
      Maintenance tolerance 0.3%
   b. On special tests:
      Acceptance tolerance and maintenance tolerance 0.5%

Inspection:

1. Indicating and recording elements.

   Design:

   Device must be equipped with indicating elements and MAY be equipped with a recording element. . . . . S.1.1.

   Units are to be in terms of gallons, quarts, pounds, or binary-submultiples or decimal subdivisions of the gallon. . . . . S.1.2., S.1.2.3.

   Readability:

   Indicating and recording elements must be clear, definite, and easily read. . . . . G-S.5., S.1.4., S.1.5.

   Required markings shall be distinct, easily

FIGURE 6-1. Page of Examination Procedure Outline (EPO) for Loading-Rack Meters.

A subsequent portion of the EPO presents a step-by-step procedure for conducting performance tests in the field. In all, this EPO has four main sections, which we will look at in turn in this chapter and the next.

Because of its systematic organization, the EPO is a useful guide for the inspector in the field. It is also a tool that can be used in the course of conducting an examination: the EPO can be used by the inspector as a checklist to ensure that all the steps in the examination have been performed.

The EPO for loading-rack meters also includes a special section that provides guidance for repair personnel, describing how they should test the equipment before it undergoes a weights and measures examination. In addition, worksheets are provided for determining meter error in accordance with the procedures set forth in the EPO. These worksheets are also intended primarily for repair personnel, but weights and measures officials whose jurisdictions do not have a report form that runs through the corrections step by step may also find them useful.

The EPO is intended as an outline of what should be considered a minimum examination procedure. When you encounter a device that has features that are "new" to you, or in non-routine examinations (conducted in response to complaints, or when there is reason to suspect that the device is being used improperly or to facilitate fraud), further examination procedures are likely to be needed.

The entire EPO for loading-rack meters is reproduced in Appendix A of this manual. This EPO should be updated periodically to incorporate changes in Handbook 44 or in the codes or policies of your jurisdiction.

An official field examination consists of four major components:

- The Inspection, to determine compliance with specifications and other requirements,
- Pretest Determinations, to assure correct application of tolerances and other test factors,
- The Test, to determine compliance with performance requirements, and
- The Evaluation of Inspection and Test results followed by approval or rejection of the device.

This division is based upon distinctions that are observed in Handbook 44 and in the EPO. The EPO covers the first three of these components (Evaluation will be described in Chapter 8 of this manual). Note that the terms "inspection," "test," "evaluation," and "examination" are used to refer to specific, different activities (the examination comprising the other three). These distinctions will become clear as we discuss the separate components in concrete terms.

PRETEST DETERMINATIONS

The first section of the EPO prescribes nine Pretest Determinations. Pretest determinations relate primarily to test equipment and other factors involving the Test portion of the Examination, rather than the Inspection, which is covered second. However, their position at the beginning of the EPO is logical from the point of view of procedure: if these items can not be verified it will not be possible to complete the Examination. So conducting an Inspection could be a waste of time.

In fact, many of these items should be checked before you depart for the test site. If, for example, the design of the prover available for the test is not compatible with the metering system (Item 3), other provisions will have to be made; arriving at the site with the wrong prover would simply be a waste of time for both you and the device operator, who may be seriously inconvenienced by rescheduling.

The items specified in the EPO can, for the most part, be verified by visual examination of the prover or consulting past examination reports that are kept on file by the jurisdiction. If necessary, required information

may be obtained from the manager of the facility or operator of the equipment. As always, taking clear and complete notes, documenting each step of the examination for future reference, will repay the effort.

Let's look at each of the Pretest Determinations in turn. All items relating to test equipment apply whether the equipment is the property of the jurisdiction or the device operator.

1. Prover must have valid calibration certificate and security seals must be intact on sight gauge.

   This assures that the prover to be used has been tested and calibrated in accordance with correct metrological procedures, and by a metrologist or laboratory approved by the jurisdiction, using standards traceable to national standards maintained by NIST.

   The calibration certificate should show a date of expiration later than the date of test.

   Security seals are affixed to the sight gauge and scale plate at the time of calibration. If they are intact, you can be assured that no unauthorized adjustments have been made.

2. Prover capacity must be sufficient to hold an amount of product which would be delivered by the meter to be tested during 1 minute of flow at its maximum discharge rate. (LMD Code, Sec. N.3.5)

   > N.3.5. WHOLESALE DEVICES. - The delivered quantity should be equal to at least the amount delivered by the device in one minute at its maximum discharge rate, and shall in no case be less than 200 L (50 gallons).
   > (Amended 1987 and 1996)

   Inertial factors associated with starting and stopping the meter introduce a small amount of inaccuracy into the measurement. This requirement assures that the meter will be operated for at least 1 minute, and will, therefore, maintain a "steady state" (that is, a steady speed, without accelerating or decelerating) for long enough to render starting and stopping errors proportionately insignificant.

   The full flow rate of the meter should be recorded on test reports from previous examinations. It is not necessarily the same as the maximum rated flow rate marked by the manufacturer on the meter; however, since the actual flow rate may not be greater than the maximum rated rate (LMD Code, Sec. UR.2.2.), a determination based upon the latter will be "safe."

3. Prover and system design must be compatible (top loading or bottom loading).

   As explained in Chapter 5, provers are tested and calibrated for use with a system that uses the loading method (top vs. side/bottom fill) for which the prover was designed. Use with a non-compatible system can produce an unacceptable level of uncertainty in test results.

   For example, if a top-loading prover is used to test a bottom-loading system, the system discharge line will have to be held manually above the prover inlet and it may be impossible to attach standard fill spouts to the outlet. Testing without the fill spout would be unacceptable both from the point of view of safety and accuracy.

4. Thermometers are to be accurate to within 0.2 /F, have a range of at least 0 /F to 120 /F, and be divided in increments of no greater than 0.5 /F. Thermometers may be of the partial immersion or digital type.

The importance of accurate temperature measurement was explained in Chapter 4. These specifications also assure that readings can readily be made to the nearest 0.5 /F, as required by the Test procedure (see Chapter 7).

Thermometer wells on the prover and meter should also be checked to make sure that they are clean and free of material that could interfere with accurate temperature measurement.

5. Inspect prover's interior surface for dents, product clingage, rust, water, or other foreign material.

Damage to the prover shell or foreign material inside can significantly affect its capacity, and water or other foreign material may contaminate product that is to be returned to storage.

Because vapors remaining inside the prover may be toxic and/or flammable, you should not place your head inside the prover neck for this visual inspection. An extension mirror and explosion-proof flashlight should be used.

6. Prover sight glass must be clean and fittings must not leak.

A clean sight glass helps assure accurate readings. Leaks anywhere on the prover should be reported and repaired immediately for reasons of both safety and accuracy. Because of the narrow circumference of the neck on many provers, a relatively small loss of liquid can result in a disproportionate decrease in level.

7. Available test fluid must be of the same general physical characteristics as that of the liquid to be commercially measured by the device. (LMD Code, Sec. N.1.)

The physical properties of the liquid passing through a meter, especially its viscosity, volatility, and thermal expansion, can significantly affect performance. Product density must be known in order to perform temperature compensation.

Since you will be testing at a permanent facility, it is unlikely that the product used for the test will be different from that normally metered. However, you should ascertain the product identity and its specific gravity (or, for petroleum products, API gravity) for later reference (see Chapter 7). If these are different from the product identity marked on the loading rack for that meter, ask the operator to explain the discrepancy.

8. For top loading provers, the prover inlet must be lower than the outlet of the meter discharge line.

The fill spout should drop vertically from the meter outlet into the prover. If it does not, complete drainage after the conclusion of the delivery may not be possible.

9. Determine applicable tolerance values. (Gen. Code G-T.; LMD Code T.1., T.2.3.)

The meaning and theory of tolerances will be discussed in some detail in Chapter 7. It will suffice for now to define tolerances as the legal limits of inaccuracy for a weighing or measuring device. With

respect to liquid-measuring devices, tolerances apply to meter error (quantity indicated by the metering system minus actual quantity delivered to the prover). Tolerances apply to both plus errors (overregistration) and minus errors (underregistration).

Tolerances for loading-rack meters are expressed in terms of a percentage of the indicated quantity. Three different tolerances are specified in the LMD Code for tests of wholesale devices such as a loading-rack meters: two apply to "Normal Tests" and one applies to "Special Tests" (the meaning of these terms will be explained in Chapter 7). The tolerances specified in the LMD Code for loading-rack meters (Section T.2.3.3.) are also listed in the EPO.
For the test of any given metering system, only one of the tolerances for Normal Tests is applicable. The applicable tolerance for a Normal Test depends upon whether it is a test for "maintenance" or "acceptance." (Acceptance and maintenance tolerances for Special Tests are the same.)

T.2.3.3. MEASUREMENT OF OTHER LIQUIDS. - Maintenance and acceptance tolerances shall be:

(a) On normal tests
Acceptance tolerance 0.2%
Maintenance tolerance 0.3%

(b) On special tests
Acceptance and maintenance tolerances 0.5%

(Amended 1986 and 1987)

LMD Code § T.2.3.3.

These concepts will also be explained in detail in Chapter 7; basically they reflect the expectation that a meter's accuracy may diminish slightly with use and normal wear. According to G-T.1.:

> Acceptance tolerances apply to devices that: (1) are about to be put into commercial service for the first time, (2) have been placed within commercial service within the preceding 30 days and are being officially tested for the first time, (3) have been returned to service following official rejection for failure to meet requirements and are being officially tested for the first time within 30 days after service, (4) are being officially tested for the first time within 30 days after major reconditioning or overhaul, and (5) are undergoing type evaluation.
>
> Maintenance tolerances apply to all other equipment and devices.

To review in terms of the tolerances specified in Section T.2.3.3.:

> The acceptance tolerance for Normal Tests is 0.2 percent of the quantity indicated on the meter (not on the prover); the maintenance tolerance is 0.3 percent.
>
> The tolerance for Special Tests is always 0.5 percent of the indicated quantity.

The critical determination with regard to applicable tolerances is whether the test is for maintenance or acceptance. Once this is determined, you will know which of the tolerances for Normal Tests is applicable.

Applicable tolerances for meter error should be recorded on your report form. In addition, if the system is equipped with an automatic temperature compensating system (ATCS), the tolerance percentage that applies to the difference in meter error on compensated and uncompensated tests (see Chapter 7 for details) should also be recorded. In accordance with T.2.3.3 of the LMD Code, this percentage is always 0.2 percent of the test draft for mechanical ATCS and 0.1 percent for electornic ATCS.

When multiple tests are conducted at approximately the same flow rate, the device is required to repeat its indication within the requirement of T.2.3.4. or 40 percent of the applicable tolerance.

> T.2.3.4. REPEATABILITY. - When multiple tests are conducted at approximately the same flow rate, the range of the results of the flow shall not exceed 40 percent of the applicable tolerance. This tolerance does not apply to the test of the automatic temperature compensating system.
> (Added 1992)

INSPECTION

After you have completed all Pretest Determinations, you are ready to begin the Inspection. This is the second major heading on the EPO for loading-rack meters.

In the Inspection portion of an official examination, you will determine whether the metering system is in conformance with specifications and other requirements pertaining to design, installation, and operation. The extent and emphasis of your inspection will depend on a number of factors relating to the specific device being examined and the circumstances under which it is being examined. The most important of these factors are:

- your familiarity with the device,
- the age of the device,
- whether or not the device is of a type that has been evaluated, and
- whether or not a complaint has been received.

Naturally, your previous experience with the particular device will have an impact upon the inspection process. If you are checking a particular make or design of meter for the first time, you may want to perform an extensive inspection that includes a careful check of all applicable requirements in Handbook 44, including those concerned with design and installation. If you are checking a device that you are familiar with, one that has been in service for some time, you may not need to spend as much time on design and installation requirements; however, you will want to look for such things as fraudulent use or abuse, or inappropriate applications of the equipment.

The age of the device -- when it was manufactured and when it was put into commercial service -- is important because a number of requirements in Handbook 44 are nonretroactive as of a certain date. As a result, you will find that older equipment may be required to meet a different set of requirements than newer equipment.

In some cases, the devices you will be examining will be of a type that has been evaluated under the National Type Evaluation Program (NTEP). NTEP is a program of the National Conference on Weights and Measures

(NCWM) for determining conformance of a weighing or measuring device "type" or "model" with the relevant provisions of Handbook 44.

Manufacturers voluntarily submit models or prototypes of their devices for evaluation under NTEP. An authorized State laboratory conducts the evaluation. When a device is found to meet all applicable requirements, NCWM issues a Certificate of Conformance for that device. The Certificate provides details of the evaluation results and device characteristics necessary for use in commerce.

Before testing a new type of device, you should determine whether a model of the device has been type evaluated. If it has, you should review the Certificate of Conformance to determine which features have been evaluated. In the past, the NCWM has issued a "National Type Evaluation Program Index of Device Evaluations" (NCWM Publication 5) to help you determine whether a particular device has been evaluated. The Index, which includes listings by company, device category, and identification number, is now available on the internet at www.nist.gov/ntep. Your instructor will tell you how to obtain a copy of the Certificate of Conformance for any device that has been evaluated under NTEP.

During the type evaluation process, extensive tests are performed in a laboratory setting to determine whether a particular device model meets all applicable requirements in Handbook 44. Some of these tests would be very difficult or impossible to conduct in the field. Consequently, the existence of a Certificate of Conformance can make your job easier -- during a routine field examination you may not have to examine extensively certain design criteria on a device that has received type approval. But remember that type evaluation means that a model of the device has been tested, not each device of that type in service. Thus, you should still review all applicable requirements when inspecting a new device. This review may consist of a brief visual check of the item.

Weighing and measuring devices are designed with specific applications in mind. Some are designed for a narrow range of applications, whereas others have a multitude of features to satisfy many different applications. Not all features are suitable for all applications. A Certificate of Conformance will state the intended application of a device type. If you encounter a new device or a feature on a device in an unusual application, it should be thoroughly tested to determine its appropriateness and to assure that it does not facilitate fraud.

Another factor that affects the nature and extent of your inspection is the existence of a complaint about a particular device or the practices of a device owner or operator. You may want to perform a more rigorous inspection than usual if your office has received complaints about a device or business.

As you will see in the detailed discussion that follows, most Inspection determinations are made on the basis of a careful visual check and the inspector's experience and knowledge of the device. This does not mean, however, that the Inspection may be approached casually, or that compliance with any requirement can be taken for granted just because the device has received type approval. It is not at all uncommon to discover items of nonconformance in a number of areas covered by the Inspection, especially when the equipment is old or has not been properly maintained. Furthermore, it is much more likely that modifications intended to facilitate fraud will show up in the course of a careful inspection than in the results of performance tests.

You should also keep in mind that your inspection is never limited to visual means, or any other. It is your responsibility as the inspector to decide what is necessary to adequately determine the compliance status of the device. If you have reason to believe that a correct determination requires additional testing, either in the field or under more controlled conditions, you should consult your supervisor so that appropriate arrangements can be made. However, the cost of additional testing to the owner or operator of the equipment, including the cost of lost productivity while equipment is out of service, must not constitute an unreasonable burden. The decision to conduct further testing will generally involve weighing the probability that a suspected violation will be confirmed against the cost of testing -- including the cost to the weights and measures jurisdiction. So you should be prepared to explain and justify your recommendation.

The remaining sections of this chapter will present the Inspection for loading-rack metering devices. Each of the items included in the EPO will be discussed in detail.

INDICATING AND RECORDING ELEMENTS

Design (ref. LMD Code, Sections S.1.1., S.1.2., S.1.2.3.)

According to Handbook 44, an indicating element is "an element incorporated in a weighing or measuring device by means of which its performance relative to quantity or money value is "read" from the device itself. . . ." A recording element makes a permanent record of such a "reading."

Any indicating or recording element that is used as the basis for determining the price of a commercial transaction is called a primary element. In general, only primary elements are covered by Handbook 44 specifications and requirements. All equipment covered by the LMD Code, including loading-rack metering systems, must be equipped with at least a primary indicating element.

> S.1.1. GENERAL. - A liquid-measuring device:
>
> (a) shall be equipped with a primary indicating element, and
>
> (b) may be equipped with a primary recording element.

LMD Code, § S.1.1.

Most loading-rack metering systems have only one primary indicating element, the register; but they may have more than one. For example, if a petroleum terminal has indicators both at the delivery stations and in a service building, and if the indicators in the building are used as the basis for determining the price of a delivery of product -- for example, if an employee prepares an invoice on the basis of those indications while the attendant and/or customer monitor the delivery on the indicator at the delivery station -- both sets of indicators would be considered primary indicating elements.

Similarly, totalizers are only considered primary indicating elements if they are actually used as the basis for computing a price for the product delivered. This is the case, for example, when cumulative totals are used to determine price under a consignment agreement between the operator of the device and his or her supplier.

A preset device that displays the preset amount and the running quantity remaining to be delivered should not be considered (or used) as a primary indicating device, since it does not display the quantity delivered.

Liquid-measuring devices are not required to have a primary recording element. However, many are equipped with ticket printers because they reduce the operator's effort and are consistently accurate, where hand-printed invoices take time to prepare and are sometimes inaccurate due to errors in transcription or computation made by the operator. Again, some systems may be equipped with more than one primary recording element (for example, a remote invoice printer that is used to prepare billings, while the customer receives a receipt printed at the delivery station).

Obviously, your first task as you begin your inspection of indicating and recording elements is to identify all elements in the system that meet the general definition. You can then proceed to check each one for conformance with specific design requirements.

Two such requirements relate to the units that are used to indicate quantities delivered. The first of these prescribes units that can be used.

> S.1.2. UNITS. - A liquid-measuring device shall indicate, and record if the device is equipped to record, its deliveries in liters, gallons, quarts, pints, or binary-submultiples or decimal subdivisions of the liter, gallon.
> (Amended 1987, 1994)

LMD Code, § S.1.2.

Because of the large quantities delivered, most loading-rack meters indicate in gallons. As mentioned earlier, this module does not cover test procedures for loading-rack mass flow meters that indicate quantities in terms of mass.

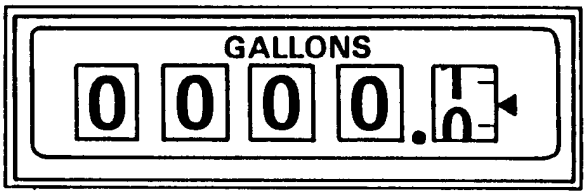
The second requirement relates to the value of the smallest unit that must be displayed in indicated or recorded representations. Remember that loading-rack meters are, by definition, wholesale devices.

> S.1.2.3. VALUE OF SMALLEST UNIT. - The value of the smallest unit of indicated delivery, and recorded delivery if the device is equipped to record, shall not exceed the equivalent of:
>
> (a) 0.5 L (1 pt) on retail devices;
> (b) 5 L (1 gal) on wholesale devices.
>
> This requirement does not apply to manually operated devices equipped with stops or stroke-limiting means.
> (Amended 1983 and 1986)

LMD Code, § S.1.2.3.

The purpose of this requirement is to minimize the impact of rounding of indicated and recorded values. The larger minimum unit for wholesale devices, such as loading-rack meters, reflects the recognition that the impact of rounding of values is proportional to the size of the delivery.

For example, if a wholesale customer is charged for 1,401 gal of product when he or she has only received 1,400.4 gal, the effect due to rounding up will only be about 0.04 percent. On the other hand, if a retail customer had to pay for 41 gal when he or she had only received 40.4 gal, the effect due to rounding would be more than 1 percent, that is, about 10 times greater even though the amount rounded is exactly the same. Reducing the smallest unit of delivery to 1 pint (0.125 gal) would mean that the retail customer would pay for 40.5 gal, and the effect due to rounding would only be about 0.25 percent.



The value of the smallest unit of indicated delivery for an analog indicator is the value of the smallest graduated interval on the quantity indication. For example, in Figure 6-2, the value of the smallest unit of indicated delivery is 1 gallon.

FIGURE 6-2. Smallest unit of indicated delivery, analog indicator.

For a digital device, the value of the smallest unit will be the smallest quantity increment, that is the smallest change in quantity that can be indicated. For example, if a digital indicator reads 20.0 gal and the next value indicated as delivery continues is 20.1 gal, the next 20.2 gal, and so on, the smallest quantity increment is 0.1 gal.

The value of the smallest unit can be determined for an analog device by observing the right-hand quantity wheel. To determine the smallest unit for a digital indicator, on the other hand, you will have to observe the device in operation. Conformance with this design requirement may be most efficiently determined, therefore, during the Test portion of the examination, when the device is actually placed in operation.

A number of requirements specifying the dimensions, character, and other design features of graduations and indicators (here used to refer to the pointer which is used in conjunction with graduations) are included in subsections S.1.4. and S.1.5. of the LMD Code. These requirements relate to analog registers only (since digital devices have neither graduations nor indicators). You should be familiar with the specifications in S.1.4. and S.1.5.; however, it is neither practicable nor necessary to check a device for conformance with each of these specifications in the course of a routine field examination, especially if you are familiar with the device being examined or have determined that it has successfully undergone NTEP evaluation.

Readability (ref. Gen. Code Sections G-S.5.1, G-S.7.)

Some of the design specifications mentioned in the last section are included in the LMD Code in order to assure that liquid-measuring devices will be readable. To minimize errors and the possibility of misrepresentation, the customer and the operator of the device must be able to read and understand the information displayed by primary indicating and recording elements. A number of requirements in the General Code (especially subsection G-S.5) also deal with the subject of readability, and provide useful guidance for a routine inspection procedure.

Paragraph G-S.5.1. states the requirement of readability for all primary indicating elements and recorded representations.

> G-S.5.1. GENERAL. - All weighing and measuring devices shall be provided with indicating or recording elements appropriate in design and adequate in amount. Primary indications and recorded representations shall be clear, definite, accurate, and easily read under any conditions of normal operation of the device.

General Code, § G-S.5.1.

Another paragraph of the General Code, G-S.7., extends the requirement of readability to all required markings, including markings on the indicating and recording elements that designate the units and instructions for operation. In addition, it requires that these markings be permanent.

> G-S.7. LETTERING. - All required markings and instructions shall be distinct and easily readable and shall be of such character that they will not tend to become obliterated or illegible.

General Code, § G-S.7.

However, Handbook 44 does not set forth any objective standard for readability, and it is doubtful that a single standard could be found that would be suitable for devices under all operating conditions.

One practical guideline can be given: the device should be readable from any reasonable "customer" position. As you inspect the register or other primary indicating element, place yourself physically in the position from which a customer would normally monitor delivery. Would a customer in this position -- one who may not be as familiar as you are with the device -- be able to read and understand the indications? If not, is it because the indications are somehow obscured, either by their position or by dirt, grease, or scratched or broken glass? Or is it the size, character, or some other design feature that makes them unreadable? If the latter, you may wish to check the specifications set forth in the LMD Code, especially subsections S.1.4. and S.1.5. to determine the specific item of nonconformance.

Values of Intervals (ref. Gen. Code, Section G-S.5.3.)

The values of the graduated intervals between successive graduations in a series of analog indications, or the values of the increments of a series of digital indications or recorded representations, must be the same throughout the series.

> A graduated interval is the distance from the center of one graduation to the center of the next graduation in a series of graduations.
>
> The value of the minimum graduated interval is the value represented by the interval from the center of one graduation to the center of the successive graduation. Also, the increment between successive recorded values.

For example, successive graduations on the right-hand indicating wheel of an analog loading-rack meter register can not have values of 1, 2, and 10 gallons, since the values of the graduated intervals (1 and 8 gallons) would not be uniform. The wheel would have to have either a single series of 1-gallon graduations or a series of 10-gallon graduations, each with a complete series of 1-gallon subdivisions.

> An increment is the value of the smallest change in value that can be indicated or recorded by a digital device in normal operation.

Similarly, a digital indicator can not display successive quantities of 1, 2, and 10 gallons: the increment would have to be uniformly either 1 gallon or 10 gallons (on loading-rack meters, the increment would have to be 1 gallon, since S.1.2.3. specifies a smallest unit of not more than 1 gallon).

A subparagraph of G-S.5.3. (G-S.5.3.1.) states that devices designed to indicate or record more than one unit of measurement must use appropriate words, symbols, or abbreviations to identify the units. Thus, for example, a digital indicator designed to display the quantity of a delivery simultaneously in terms of gallons and liters would need to use the words "gallons" and "liters" (or appropriate abbreviations) to clearly identify the values displayed. (Note that this requirement is retroactive as of January 1, 1990).

The purpose of both these requirements is to prevent indications that could be misread or misinterpreted. You should make a point of observing the indicators while the device is operating to verify that the values of intervals are uniform.

Advancement and Return to Zero (ref. LMD Code, Section S.1.3.)

According to the LMD Code, a device must be designed so that its primary indicating and recording elements can not be advanced unless the device is operating and product is being measured.

> S.1.3. ADVANCEMENT OF INDICATING AND RECORDING ELEMENTS. - It shall not be possible to advance primary indicating and recording elements except by the mechanical operation of the device. Clearing a device by advancing its elements to zero is permitted, but only if:
>
> (a) once started, the advancement movement cannot be stopped until zero is reached, and
>
> (b) in the case of indicating elements only, such elements are automatically obscured until the elements reach the correct zero position.

LMD Code, § S.1.3.

The purpose of this requirement is to prevent someone from manipulating the indicating and recording elements so that they indicate more product than was actually delivered.

Devices may be returned to zero by advancing their indicating or recording elements; however, in this case, they must be designed so that an intermediate value can not be shown or printed before the device returns to zero.

Most mechanical registers are equipped with shutters that are actuated automatically when the reset control begins. These shutters obscure the value wheels while they are turning and are retracted, again automatically, when the indicator has reached the zero stop.

Most electronic registers blank out the display completely during the reset process, displaying the figure '8' for all digits momentarily just before zeros appear. (This is a segment check of the display: since the figure '8' includes all the independently activated display segments that are used to display the other numerals, this test assures that all display segments are operative.)

The most efficient means of determining whether the device meets this requirement is to observe the register during the Test, when it will be reset several times. Once the reset mechanism has been actuated, you should be able to see no more significant indications until the reset is complete and a zero indication appears.

Provision for Sealing (ref. Gen. Code G-S.8., G-UR.4.5.)

Some means of adjusting or recalibrating the measuring and registrating elements of a metering system is necessary. Without such a mechanism, expensive components would have to be replaced as soon as they were no longer capable of meeting close-tolerance performance tests, and the cost of this replacement would be passed on to the consumers of metered products. However, any adjusting mechanism may be used to facilitate fraud unless some means is available to assure that it is not manipulated by the operator to affect the measurement or registration of the device.

Sealing a device provides a reasonable level of assurance. Sealing does not actually prevent a device from being manipulated, but makes it impossible to do so without leaving evidence. Handbook 44 requires that means be provided for sealing adjustable elements of devices that can affect measurement, and also requires that seals be installed and maintained intact by device users. Physical seals, such as lead-and-wire seals, have been used for many years by weights and measures jurisdictions to perform this function. However, recent developments in technology have resulted in new methods of sealing, as will be explained below.

In addition to an adjustment for meter error, if a system is equipped with devices that automatically compensate for variations in product temperature, density, or pressure, there will also be means for setting or adjusting these correction devices. Any of these adjustments can affect measurement accuracy.

As you have learned, the amount of product that passes through a positive-displacement or turbine meter per meter cycle cannot readily be changed. So, when a metering system requires adjustment or recalibration, the adjustment affects the registration. As described in Chapter 3, the adjustment can be made in one of two basic ways:

- by altering the ratio of the speed of the meter output shaft to the speed of the register (or pulser) input shaft, by changing gears or some similar mechanical method, or

- by entering a calibration or adjustment factor into the memory of an electronic register; this factor automatically corrects the registration by computation rather than by altering the physical input.

The latter method is obviously limited to electronic systems. However, many electronic systems can be adjusted both electronically and mechnically, even if, in practice, the electronic adjustment is used exclusively. The

inspector should, therefore, also check electronic systems to ensure that provision has been made for sealing of mechanical adjustors.

A mechanical adjustor, such as a ratio changer, is located between the meter and the register (or between the meter and the pulser). Although it affects registration, the adjustor itself is considered to be a part of the measuring element. Requirements for sealing this type of adjustor, and for sealing of automatic temperature compensating systems, will be described under MEASURING ELEMENTS, below.

In many newer electronic systems, all quantity registration and correction functions are integrated within a single device: the "register" receives input from the meter pulser, and possibly from a temperature probe. The device is preset by the operator for the specific gravity of the product, with a pressure correction factor (for certain products), and with a calibration factor determined by proving. If the device indicates both net and gross deliveries, there may be separate calibration factors for the temperature probe and for the meter. These may all be referred to as correction factors.

The system processor uses the factors entered by the operator to continuously compute the corrected quantity delivered. Because the correction factors are retained by the system, the operator does not reenter them for each delivery, but only when the conditions which they reflect have changed.

Because altering any of the correction factors will affect the measurement to some degree, sealing of the adjustment mechanisms is appropriate. The General Code includes a requirement that applies specifically to electronic adjustable components.

> G-S.8. PROVISION FOR SEALING ELECTRONIC ADJUSTABLE COMPONENTS. - A device shall be designed with provision(s) for applying a security seal that must be broken, or for using other approved means of providing security (e.g., data change audit trail available at the time of inspection), before any change that detrimentally affects the metrological integrity of the device can be made by any electronic mechanism.
>
> [Nonretroactive as of January 1, 1990.]

General Code, § G-S.8.

The term "metrological integrity" refers generally to the validity of measurement or proper operation of the device: in accordance with G-S.8., any functions, parameters, and features of a device that can be modified and that can affect the integrity of a transaction must be sealed. In the case of loading-rack meters, this could apply to the following elements (although some systems may not have or use all of them):

- a correction for the temperature probe
- pressure corrections for some types of products
- density correction factors for some products
- a calibration factor for the meter

Some electronic registers employ switches or some other electro-mechanical means for entering correction factors. There is usually one set of switches for each correction factor. To prevent accidental or unauthorized resetting, the switches are located behind a panel or door with a lockable or sealable latch or hasp. For such

devices, a lead-and-wire type seal, installed in such a way as to prevent access to the switches without breaking the seal, is generally an effective method of sealing.

In many newer devices, correction factors are stored in programmable electronic memory, and are entered from a multi-function keypad. The keypad may be permanently installed, or it may be a module that can be connected directly to the register by cable. The system may also be set up so that corrections can be entered from a remote location, such as a computer in the terminal office. To prevent unauthorized resetting, electronic access to the programmable memory is permitted only after the operator has correctly entered a password; if the password is not correctly entered, the system will not accept input from the keypad.

For this type of device, a physical seal (e.g., preventing access to the keypad or to the cable connection) may be impractical, especially if the keypad is used for other functions, such as entering a customer code or quantity preset amount, which are necessary for normal operation and which do not affect the measurement. Paragraph G-S.8. therefore recognizes that there may be other acceptable ways of effectively sealing the adjustable elements.

One such method, mentioned in the requirement, is an audit trail. This is simply an electronic record that is made each time a portion of the device memory that holds data that can affect the "metrological integrity" of the device and that can be modified by the operator is accessed. The audit trail may consist of a simple count of the number of times the memory was accessed, or it may include additional information, such as the date and time of each access, a record of the specific values that were changed, and a code that identifies the person who performed the access.

To be effective, the audit trail must be created automatically by the system, there must be no means of changing or deleting a record once it is made, records must be maintained in system memory (even during an extended power failure) for a sufficient period of time to provide a history extending back in time at least to the last weights and measures examination, and the audit trail must be accessible to the weights and measures inspector.

However, because of the variation in design and the technical complexity of these systems, it is impossible to state specifications that would cover all devices available on the market. The best guidance in inspecting a system of this kind will be provided by a NTEP Certificate of Conformance. If you are inspecting a device that has not been type-evaluated, you should consult your supervisor for guidance. Your instructor will explain any special policies or procedures that your jurisdiction has regarding sealing of electronic components.

The General Code includes a user requirement that security seals must be installed on any adjustable element that can be sealed.

> G-UR.4.5. SECURITY SEAL. - A security seal shall be appropriately affixed to any adjustment mechanism designed to be sealed.

General Code, paragraph G-UR.4.5.

For electronic devices that employ physical seals, the inspector should check carefully that they are intact. If the seals bear any special marking this should be checked, and if they are dated, the date should be checked against past records. If there is evidence that a seal has been removed, the inspector should demand a complete explanation and documentation from the owner or operator.

Although G-UR.4.5. refers specifically to seals that are "affixed," it could be interpreted as applying also to an electronic sealing technique, such as an audit trail: the program that creates the records must be active at all times, and the records themselves must be maintained continuously, even during extended power failures.

The location of all seals in place at the conclusion of the examination should also be recorded, so that they may be checked at the next regular inspection. Procedures for affixing security seals are described in Chapter 8.

MEASURING ELEMENTS

After this lengthy discussion of the numerous and detailed specifications relating to the indicating and recording elements of a loading-rack metering system, it may seem surprising to you that Handbook 44 has no specifications for the design of the meter itself, except that provision be made for sealing it. Of course, the entire metering system is required to perform accurately within close tolerances, and this performance, which you will test in the course of your examination, depends to a large degree upon the condition of the meter. However, the design and operation of the types of meters that are usually incorporated in loading-rack metering systems is relatively simple from a mechanical point of view, and both very effective and very reliable.

Although there are no specific requirements for the meter, Handbook 44 does specify several aspects of the design of auxiliary components of the measuring system: the vapor eliminator and temperature-sensing devices. In addition, several requirements relate to provisions for sealing.

Vapor Elimination (ref. LMD Code, Section 2.1.)

As you know, to provide accurate measurement, a loading-rack metering system must be designed in such a way that air and/or vapor does not pass through the meter. The LMD Code requires that all liquid-measuring devices be equipped with an automatic means to prevent metering of gases.

> S.2.1. VAPOR ELIMINATION.
>
> (a) A liquid-measuring device shall be equipped with a vapor or air eliminator or other automatic means to prevent the passage of vapor and air through the meter.
>
> (b) Vent lines from the air or vapor eliminator shall be made of metal tubing or other rigid material.
>
> (Amended 1975)

LMD Code, § S.2.1.

This paragraph does not, however, require that all metering systems be equipped with an air/vapor eliminator, only that they be equipped with some automatic means to prevent air or vapor from passing through the meter. If, as is the case for many loading-rack metering systems, the system is so designed that air is not introduced into the flow and vapor is not generated in the supply line, an air eliminator is not necessary. For example, a system might have a low-liquid-level sensor located in the storage tank that would automatically shut down the system when the liquid in the tank reached a certain level, thus preventing the tank from completely emptying and, consequently, preventing air from being drawn into the system.

Unfortunately, it is impossible to determine from visual inspection, and nearly impossible to determine from the limited testing that is performed during the examination, whether the design of the system is effective.

Excessive air or vapor entering the meter may be signalled by the register jumping during operation, rather than advancing smoothly. But this is difficult to detect on a digital indicator. Furthermore, the absence of register jump does not positively preclude the possibility that air or vapor is being metered.

Similarly, erratic performance or poor repeatability may indicate the presence of air or vapor; however, these are also symptoms of a worn meter and extensive testing would be required to confirm air or vapor as the cause.

In short, if the system is not equipped with an air/vapor eliminator, ask what automatic means is incorporated in the system to prevent the metering of air and vapor. If you receive a satisfactory response, and if there is no obvious indication of a problem that can be attributed to metering air/vapor, then the system can be recognized as meeting the vapor elimination requirement.

You should establish by inspection whether the system is equipped with an air eliminator. You will recall its general features and location from our discussion in Chapter 3. You should be able to locate the vent line that carries expelled gases from the eliminator. Any obstruction to the venting of gases from the chamber would force them to pass through the meter, defeating the purpose of the device and perhaps aggravating the problem. So, this line must be of a rigid material, and should show no evidence of crimps or breaks.

For the same reason, there should be no valve on the vent line, or other means of interfering with the venting of air and/or vapor. The presence of any such means would constitute facilitation of fraud, in violation of Section G-S.2. of the General Code.

Provision for Determination of Temperature (ref. LMD Code, Section S.2.6.)

As you have learned, relatively small differences in temperature between product in the meter and in the prover can affect test results significantly. In order to obtain accurate test results, it must be possible to observe and record the temperature of product at the meter, so that adjustments can be made to the prover volume, if necessary.

Section S.2.6 of the LMD Code therefore requires that some means be provided on devices without ATCSs to determine the temperature of product, either in the meter chamber itself or in the supply or discharge line immediately adjacent to the meter inlet or outlet. (Note that this requirement is nonretroactive as of January 1, 1985, and that there is a similar requirement for devices with ATCSs, which is discussed below.)

This requirement can be met by a thermometer well, into which an accurate thermometer can be inserted during the Test. Note that any temperature-sensing device used for official tests, whether supplied by the operator or by the weights and measures jurisdiction, must meet the specifications described above (under Pretest Determinations).

S.2.6. TEMPERATURE DETERMINATION, WHOLESALE DEVICES EXCEPT MASS FLOW DEVICES. - For test purposes, means shall be provided to determine the temperature of the liquid either:

(a) in the liquid chamber of the meter, or

(b) immediately adjacent to the meter in the meter inlet or discharge line.

[Nonretroactive as of January 1, 1985.]
(Added 1984; Amended 1986)

LMD Code, § S.2.6.

A thermometer well should have a removable cover, which should be closed when the well is not in use to prevent dirt, grease, and other foreign material from falling into the well and inhibiting heat transfer to or from the thermometer when it is inserted. Locate the meter thermometer well and check to see that it is in suitable condition for use.

Section S.2.7.4. repeats, nearly word-for-word, the requirement of S.2.6. that the system must provide a means of determining the temperature of product in or immediately adjacent to the meter. It should be noted, however, that Section 2.6. applies to wholesale devices, whether or not they are equipped with ATCSs, and is non-retroactive as of January 1, 1985. Section 2.7.4., on the other hand, applies specifically to wholesale devices with automatic temperature compensation, and is retroactive.

Provision for Sealing (ref. Gen. Code G-UR.4.5.; LMD Code S.2.2., S.2.7.3.)

As mentioned earlier, many metering systems -- both electronic and mechanical -- incorporate a means of adjusting registration by changing the ratio of the speed of the meter output shaft to the speed of the register (or pulser) input shaft. Paragraph S.2.2. of the LMD Code requires that this adjustment be sealed.

S.2.2. PROVISION FOR SEALING. - Adequate provision shall be made for an approved means of security (e.g. data change audit trail) or physically applying security seals in such a manner that no adjustment may be made of:

(a) any measurement element, or

(b) any adjustable element for controlling delivery rate when such rate tends to affect the accuracy of deliveries. When applicable, the adjusting mechanism shall be readily accessible or purposes of affixing a security seal.

(c) Audit trails shall use the format set forth in Table S.2.2.
[*Nonretroactive and enforceable as of January 1, 1995.*]
(Amended 1991, 1993 and 1995)

LMD Code, paragraph S.2.2.

In many cases, the adjustment mechanism is enclosed, so it is often most efficient and effective to seal the access to the control, rather than the control itself. In some mechanical systems, the adjustor is actually inside the meter housing, and access is gained by unbolting the register or quantity preset that sits on top of the meter from the meter. In this case, the meter and register are sealed together by passing a seal wire through the drilled end of one or more of the mounting bolts (Figure 8-1, in Chapter 8, illustrates this technique).

If the adjustor is not enclosed within the meter, it should either be protected by a sealable door or panel, or by a sealable locking mechanism. Even if this is the case, it may also be advisable to seal the top of the meter, to prevent tampering with the gears or other parts of the transmission mechanism.

In accordance with S.2.2(b)., any means of adjusting or altering the discharge rate, especially upstream of the meter, must also be sealed when the flow rate affects the accuracy of deliveries. This might apply, for example, to an adjustor for the quantity preset or control valve that makes it possible to alter the setpoint for the discharge rate.

When inspecting a device, especially one with which you are not familiar, look for all possible ways that access to adjustable elements might be gained, and ask the operator to review the provision for sealing each.

Another paragraph of the LMD Code extends the requirement for sealing of measuring elements specifically to automatic temperature compensating systems (ATCSs). Note, however, that paragraph S.2.7.3. specifies sealing not only of the adjustment mechanism, but also to ensure that the ATCS can not be diconnected.

> S.2.7.3. PROVISION FOR SEALING AUTOMATIC TEMPERATURE COMPENSATING SYSTEMS. - Provision shall be made for applying security seals in such a manner that an automatic temperature-compensating system cannot be disconnected and that no adjustment may be made to the system without breaking the seal.

LMD Code, paragraph S.2.7.3.

You may encounter mechanical temperature compensators, especially on older equipment. The compensator is located between the meter and the register or preset in the meter "stack," and functions as an automatic ratio changer. Sealing this type of compensator to both the meter below and the component above (register or preset) effectively prevents it from being disconnected without leaving evidence and may also, depending upon the design, prevent access to the adjustor. If access to the adjustment mechanism for the compensator can be gained without dismantling the meter stack, the adjustor itself should also be sealed appropriately. To further ensure that the compensator can not be disconnected, the temperature probe should also be sealed where it is connected at the meter or piping and also where it is connected to the compensator.

Paragraph G-UR.4.5., which was described earlier, and which requires that a security seal be appropriately affixed to any adjustment mechanism, also applies to the seals described here. You should check all existing seals to determine that they are properly installed and intact. If any are missing or damaged, ask the operator for an explanation. You should record the location of all seals in place at the conclusion of your examination, so that they may be checked at the next regular inspection. Procedures for installing security seals are described in Chapter 8.

Deactivation of automatic temperature compensating mechanism (ref. LMD Code Section S.2.7.2.)

As you will learn, the test procedures for loading-rack meters equipped with automatic temperature-compensating devices involve comparing meter performance with the device activated and with it deactivated, the assumption being that any significant difference in performance may be attributable to the temperature compensator. Therefore, Section S.2.7.2. of the LMD Code requires that provision be made for deactivation of the temperature-compensating mechanism during testing.

> S.2.7.2. PROVISION FOR DEACTIVATING. - On a device equipped with an automatic temperature-compensating mechanism that will indicate or record only in terms of gallons compensated to 60 /F, provision shall be made for deactivating the automatic temperature compensating mechanism so that the meter can indicate, and record if it is equipped to record, in terms of the uncompensated volume.
> (Amended 1972)

LMD Code § S.2.7.2.

Electronic ATCSs generally have a switch that will deactivate them, located behind a panel on the device. If you are unfamiliar with the particular model you are examining, ask the operator to show you where the mechanism for deactivating the ATCS is located and how it works.

Note that in accordance with Section S.2.7.3. (discussed above, under Measuring Elements, Provision for Sealing), that the means for deactivating the device must be sealed, so that it can not be manipulated by the device operator to activate the ATCS only when the resulting adjustment will be in his favor.

INSTALLATION

General

Even a metering system that is suitable for its application may not perform accurately and consistently if it has not been installed properly. For example, the use of piping or connectors with dimensions other than those specified by the manufacturer can affect various operating characteristics of the system and these, as you know, can in turn affect the accuracy of measurements. Proper installation of loading-rack metering systems also involves important considerations of safety and security.

As a means of assuring that the system performs as it was designed to, the General Code requires that the manufacturer's instructions be followed in installing the meter and accessory equipment. A requirement in the LMD Code (UR.2.1) states the same requirement, in a somewhat abbreviated form.

> G-UR.2.1. INSTALLATION. - A device shall be installed in accordance with manufacturer's instructions, including any instructions marked on the device. A device installed in a fixed location shall be so installed that neither its operation nor its performance will be adversely affected by any characteristic of the foundation, supports, or any otherdetail of the installation.

General Code, § G-UR.2.1.

It is neither practical nor, generally speaking, necessary to check each item in the manufacturer's instructions as part of a routine field examination. You should at least, however, determine by a visual inspection whether the meter and register are properly mounted, and whether there is any exposed electrical wiring. As you proceed

through the examination, results from inspecting and testing particular elements of the system may lead you to the conclusion that a substandard condition or performance is ultimately the result of improper installation.

Several more installation requirements apply to specific components or aspects of the system.

Discharge Rate (ref. LMD Code, Section UR.2.2.)

One of these specific requirements relating to installation is intended to prohibit any installation that would allow the metering system to be operated at a discharge rate higher than its rated maximum. As you have learned, exceeding the maximum rated flow rate may affect the accuracy of the meter.

> UR.2.2. DISCHARGE RATE. - A device shall be installed so that the actual maximum discharge rate will not exceed the rated maximum discharge rate. Automatic means for flow regulation shall be incorporated in the installation if necessary.

LMD Code, § UR.2.2.

To some degree, the maximum discharge rate that can be developed is effectively limited by such factors as the inside diameter of the piping and the design of the pump (provided, of course, that the system has been installed in accordance with the manufacturer's specifications). However, in some systems, additional means of controlling flow rate are necessary.

This is often accomplished by a pilot-operated control valve, which is actuated either mechanically or electrically in response to a rate-of-flow sensor located on the discharge side of the meter. This is one of the functions of the control valve we discussed in Chapter 2.

The most important part of the requirement is that any such valve must be automatic: it must shut off flow of product when the calibrated flow rate is exceeded, without requiring any action on the part of the operator. A system incorporating a flow rate indicator or gauge and a manual throttling valve as a means of preventing excessive discharge rates will not meet this requirement, since these means would not be automatic. (Such mechanisms are, however, appropriate for controlling flow rate within the rated range, and are not prohibited when used for that purpose.)

Facilitation of Fraud (ref. Gen. Code, Section G-S.2.)

It is especially important to determine that the equipment, as installed and operated, does not tend to facilitate fraud. It is not necessary to prove or even have evidence that the operator is actually using the equipment to perpetrate fraud, only that the design or installation could be used fraudulently. The assurance that the potential for abuse of weighing and measuring equipment has been minimized is essential both for consumer confidence and equity in the marketplace. The General Code includes a broad requirement relating to facilitation of fraud.

> G-S.2. FACILITATION OF FRAUD. - All equipment and all mechanisms and devices attached thereto or used in connection therewith shall be so constructed, assembled, and installed for use that they do not facilitate the perpetration of fraud.

General Code, § G-S.2.

As you inspect the system, keep your eyes open for any element of the installation that seems unusual, especially valves or piping that could be used either to divert metered product (see below), restrict flow (causing vaporization), heat the product (especially at installations where temperature compensation is not employed), and so on. If you do not understand the function, design, or operation of some element in the system, ask the operator or owner for clarification.

If the owner or operator intends to defraud his customers, it is unlikely that the method will be obvious. On the other hand, unless you have cause to be suspicious, either from complaints or from your observations, there is no reason to go beyond a careful visual inspection. However, keep in mind that facilitation of fraud does not require intent: incorrect design, installation, or use may have potential for abuse that the operator himself is not even aware of.

Discharge Line (ref. LMD Code, Sections S.2.3., S.3.1.)

As just said, any means of diverting product that has passed through the meter represents facilitation of fraud. The LMD Code includes a specific requirement prohibiting diversion of measured liquid.

> S.3.1. DIVERSION MEASURED LIQUID. - No means shall be provided by which any measured liquid can be diverted from the measuring chamber of the meter or its discharge line. Two or more delivery outlets may be installed only if automatic means are provided to ensure that:
>
> (a) liquid can flow from only one outlet at a time, and
>
> (b) the direction of flow for which the mechanism may be set at any time is clearly and conspicuously indicated.
>
> A manually controlled outlet that may be opened for purging or draining the measuring system or for recirculating product in suspension shall be permitted only when the system is measuring food products or agri-chemicals. Effective means shall be provided to prevent passage of liquid through any such outlet during normal operation of the measuring system and to inhibit meter indications (or advancement of indications) and recorded representations while the outlet is in operation.
> (Amended 1991, 1995, and 1996)

LMD Code, § S.3.1.

One means of preventing diversion of measured product would be to strictly limit the use of multiple discharge lines serving the same meter, which could facilitate fraud. In fact, the LMD Code does include two exceptions (Sections S.3.2. a and b).

> S.3.2. EXCEPTIONS. - The provisions of S.3.1. Diversion Prohibited shall not apply to:
>
> (a) truck refueling devices when diversion of flow to other than the receiving vehicle cannot readily be accomplished and is readily apparent. Allowable deterrents include, but are not limited to, physical barriers to adjacent driveways, visible valves, or lighting systems that indicate which outlets are in operation, and explanatory signs;
>
> (b) other devices, when all discharge outlets designed to operate simultaneously are 3.8 cm (1.5 in) in diameter or larger.
> (Amended 1982, 1990, and 1991)

LMD Code, § S.3.2.

This exception covers most loading-rack metering systems, and was specifically intended to permit simultaneous loading of trucks with multiple-tank compartments. Such use, which is common, does not violate Section S.3.1., provided that product from a single meter is only delivered to one customer.

As you have learned, the discharge line on some loading-rack metering systems is a "wet" hose, and must be kept packed with liquid product at all times. The valve at the outlet of the discharge line should prevent the line from being drained outside the system. (A specific requirement relating to this function will be explained in the next chapter.) In addition, metered product must also be prevented from flowing from the discharge line back through the meter.

This is usually accomplished by the automatic flow control valve described in Chapter 2, which closes the flowpath either immediately upstream or immediately downstream of the meter at the end of a delivery. It may also be accomplished by means of a directional flow valve, also called a check valve, installed at the meter outlet. This valve opens only when product is flowing toward the outlet and closes when flow has ceased, effectively preventing reversal of flow through the meter. The LMD Code requires that directional flow valves be automatic in operation.

> S.2.3. DIRECTIONAL FLOW VALVES. - Valves intended to prevent reversal of flow shall be automatic in operation.

LMD Code, § S.2.3.

This prevents a situation in which the device operator can manually manipulate the check valve, permitting diversion of measured liquid back through the meter.

Any manually operated valve between the meter outlet and the discharge valve at the end of the discharge line may violate this requirement, and you should ask for an explanation of its function from the operator. If an automatic check valve is malfunctioning or has been disabled, drainage of the discharge line may be apparent in inconsistent Test results.

Leaks (ref. Gen. Code Section G-UR.4.1.; LMD Code Section S.3.1.)

Leaks are a cause of concern because they present safety and environmental hazards, and should be noted and reported to the owner or operator of the device.

In addition, leaks on the discharge side of the meter affect measurement accuracy, since they divert metered product before the purchaser has taken possession of it.

Section G-UR.4.1. of the General Code (quoted later in this section) makes it the device owner's legal responsibility to maintain equipment in proper operating condition, this includes leaks. Both this paragraph and Section S.3.1. of the LMD Code (prohibiting diversion of measured product) may be used as the authority for rejecting a metering system that has leaks on the discharge side of the meter.

Accessibility for Testing and Assistance (ref. Gen. Code Sections G-UR.2.3., G-UR.4.4.)

The metering system must be installed in such a way that all elements that are subject to inspection and testing must be accessible to the weights and measures official and to any required test equipment. For loading-rack metering systems, these elements include:

- all indicating and recording elements (the register, ticket printer, totalizers, etc.);
- the automatic temperature compensator, if the system is equipped with one;
- the meter and vapor eliminator, including vent lines from the vapor eliminator and the meter identification plate, which contains several items of important and required information (see below); and
- all piping between the storage tank and the discharge nozzle, and all automatic and manual control elements.

The General Code states that it is the responsibility of the owner or operator of a weighing and measuring device to make all equipment accessible to weights and measures officials.

> G-UR.2.3. - ACCESSIBILITY FOR INSPECTION, TESTING, AND SEALING PURPOSES. - A device shall be located, or such facilities for normal access thereto shall be provided, to permit:
>
> (a) inspecting and testing the device;
>
> (b) inspecting and applying security seals to the device; and
>
> (c) readily bringing the testing equipment of the weights and measures official to the device by customary means and in the amount and size deemed necessary by such official for the proper conduct of the test.
>
> Otherwise, it shall be the responsibility of the device owner or operator to supply such special facilities, including such labor as may be needed to inspect, test, and seal the device, and to transport the testing equipment to and from the device, as required by the weights and measures official.
> (Amended 1991)

General Code, § G-UR.2.3.

Because loading-rack metering systems are designed for direct sales and public access, and because they are periodically tested and recalibrated by the owner or operator, generally using test equipment that is similar to that used by weights and measures jurisdictions, there is usually no problem with accessibility. However, if, for example, the meter is installed in a locked cabinet, the operator must provide a key. Or if the meter or piping is obscured by housings or cabinetry, the operator must make these elements accessible by removing the obstruction.

Several steps in the examination procedures require two people to perform them safely and accurately. It is also standard procedure (as well as a matter of policy in many jurisdictions) to have the operator or an experienced employee operate the metering system, while the inspector operates only the test equipment. This minimizes any liability for damage that occurs during the examination, and is usually a more efficient procedure, since the

operator or employee will be more familiar with the system's controls, adaptors, etc., and will be available to answer questions.

Where assistance is necessary, the inspector must not attempt to perform procedures alone. The General Code requires that an assistant must be provided by the owner or operator of a device whenever necessary.

> G-UR.4.4. ASSISTANCE IN TESTING OPERATIONS. - If the design, construction, or location of any device is such as to require a testing procedure involving special equipment or accessories or an abnormal amount of labor, such equipment, accessories, and labor shall be supplied by the owner or operator of the device as required by the weights and measures official.

General Code, § G-UR.4.4.

It is obviously important that the owner or operator be notified of the need for assistance far enough in advance to allow him or her to make necessary arrangements. Your jurisdiction may have specific procedures regarding arrangements for assistance. If so, your instructor will explain them to you.

SELECTION AND USE

Selection (ref. Gen. Code Section G-UR.1.)

Loading-rack metering systems are available in a variety of designs and configurations to meet the needs of specific commercial applications. A number of usage factors are considered by the owner of the device in selecting the correct equipment, including the physical and chemical properties of the products that will be metered and the nature and volume of the business. The size and capacity of the metering system will depend to some degree upon the size of receiving tanks, the number of meters to be installed, and similar factors. The system will be designed to develop the discharge rate that will provide efficient and safe loading. A system designed for loading gasoline into large tanker trucks will obviously have different features than a system used to make deliveries to small fuel-oil trucks.

Using equipment that is unsuitable for its application is not good practice, and is generally more costly in the long run, since components will wear more rapidly and are more likely to malfunction when they are required to perform under operating conditions other than those for which they were designed. But where weighing and measuring devices are concerned, the use of unsuitable equipment can also affect the accuracy of measurement, as, for example, when a system is operated at discharge rates outside the range recommended by the manufacturer. It is for this reason that the selection of suitable equipment is required by the General Code.

> G-UR.1.1. SUITABILITY OF EQUIPMENT. - Commercial equipment shall be suitable for the service in which it is used with respect to elements of its design, including but not limited to its weighing capacity (for weighing devices), its computing capability (for computing devices), its rate of flow (for liquid-measuring devices), the character, number, size, and location of its indicating or recording elements, and the value of its smallest unit and unit prices.
> (Amended 1974)

General Code, § G-UR.1.1.

Another subparagraph of Section G-UR.1. extends this general requirement for suitability to consideration of environmental factors.

> G-UR.1.2. ENVIRONMENT. - Equipment shall be suitable for the environment in which it is used including but not limited to the effects of wind, weather, and radio frequency interference (RFI).
> (Added 1976)

General Code, § G-UR.1.2.

Environmental factors may play a particularly important role in the selection of loading-rack meters because many elements of the system are constantly exposed to wind, sun, and temperature fluctuations. Furthermore, because they are often located outdoors, they are not shielded from the effects of radio-frequency interference (RFI). RFI is generated primarily by transmitting equipment. Although equipment is generally designed with shielding capable of protecting it from moderate exposure to this type of interference, depending upon the proximity and strength of the source, RFI can affect electronic components of the metering system.

Several of the specifications covered elsewhere in the Inspection relate to the suitability of the device in regard to particular elements or features, but it is important to make a general assessment of the suitability of the equipment at the beginning of the examination.

Specific items of information, including maximum and minimum discharge rates and use limitations, are required to be marked permanently on the device (see the section below on Marking for details). The operating manual and/or installation instructions that come with the meter from the manufacturer or distributor usually include a discussion of appropriate applications, and will also mention specific applications that are not appropriate. If you are unfamiliar with the device you should check these sources. If they are not available or do not provide enough information to make a determination as to the suitability of the equipment, a local distributor, manufacturer's representative, or authorized service agency can usually answer any question you have. An NTEP Certificate of Conformance will also provide information relative to the suitability of the device.

Of course, you may have to rely upon the operator of the equipment to describe to you how it is actually used. If you have reason to doubt the accuracy of this information, check with your supervisor about making further inquiries.

Use (ref. Gen. Code Sections G-UR.3.1., G-UR.4.1.)

A precision measuring device can be expected to perform accurately and reliably only if it is used and maintained properly. Two paragraphs of the General Code establish correct use and maintenance as requirements.

> G-UR.3.1. METHOD OF OPERATION. - Equipment shall be operated only in the manner that is obviously indicated by its construction or that is indicated by instructions on the equipment.
> G-UR.4.1. MAINTENANCE OF EQUIPMENT. - All equipment in service and all mechanisms and devices attached thereto or used in connection therewith shall be continuously maintained in proper operating condition throughout the period of such service. Equipment in service at a single place of business found to be in error predominately in a direction favorable to the device user shall not be considered "maintained in a proper operating condition."
> (Amended 1973, 1991)

It may be difficult to determine whether equipment is being used properly in its commercial operation in the course of a field examination. You may, however, have an opportunity to observe a commercial transaction before or after your examination, or you might question the operator about how the device is normally used and advise him or her of the requirement quoted above. This should certainly be done if complaints have been received.

It is often possible to detect certain types of misuse or inadequate maintenance from the physical condition of the equipment at the time of the inspection. Look for evidence such as excessive dirt or grease, leaks, dents, premature wear, or frequent need for adjustment. Broken or cracked glass over the register should be cited, since it may affect the readability of indications.

The provision of G-UR.4.1 regarding equipment at a single location that errs predominately in favor of the owner is intended to discourage the abuse of tolerances. Weighing and measuring devices are required to be adjusted as close as possible to a zero error condition, not to applicable tolerances, which are the legal limits of inaccuracy.

If the owner of a number of loading-rack meters, for example, makes it a practice to adjust the metering equipment as close as possible to tolerances rather than to zero error, the cumulative effect can be a significant advantage for him or her, and a significant disadvantage to his or her customers, even though each device performs within tolerances that permit only a small degree of error. The system of tolerances can only be effective if it can be assumed that for a large number of devices that perform within tolerances, some err slightly in favor of their owner, others slightly in favor of the customers, so that the cumulative effect is truly insignificant.

In accordance with this requirement, an inspector can reject all metering devices operated from a single location even though none of them individually performs outside applicable tolerances. But such an action could obviously cause a considerable disruption of business, which could result in real hardship both for the owner and for customers who depend upon regular supplies of product for their own businesses. Handbook 44 does not provide guidelines for application of this requirement to particular situations, and any general rule that could be devised would probably be unfair, ineffective, or both under some circumstances. Your jurisdiction may have a specific policy in regard to this requirement, but even if it does, you will need to exercise careful judgment in making a determination in any particular case.

As a rule, the owner or operator who is deliberately abusing tolerances will not be eager to admit to improper and illegal practice, and it is extremely unlikely that written instructions regarding such adjustments will exist; so the evidence will generally be entirely circumstantial, and based upon your test results.

If a check of records for past weights and measures examinations reveals that this owner's equipment is usually in this condition, the pattern observed could constitute strong circumstantial evidence. Such factors as the number of meters operated from the same location, the time that has passed since the last examination, and the compliance history of the owner or operator should be taken into account whenever possible. In doubtful cases, you should seek guidance from your supervisor.

MARKING

Handbook 44 specifies a number of different items of information that must be marked on a loading-rack metering device. Requirements also relate to the manner in which this marking must be done. All required markings must be legible and easily readable. This requirement is contained in the General Code (see Section G-S.7., discussed above, under Readability of Indicating and Recording Elements).

To assure that a source of authoritative technical information is available for all equipment in commercial service, the General Code specifies that each device be marked with the manufacturer's name, the model designation, and, if it has been put in service since 1968, a unique serial number. Additionally, the model and serial numbers shall each be designated with a term which clearly identifies it as such.

The most authoritative source of technical information about a measuring device is the manufacturer. Because technical information is often needed by the operator of the device, by repairpersons, and by weights and measures officials, the name of the manufacturer must be readily available. But the company name alone is often not enough to identify the device for the purpose of obtaining specific information. Most manufacturers of loading-rack meters, for example, make more than one model of meter, and some make several. Furthermore, design changes and new features are sometimes incorporated into existing models.

As a result, the only way of positively identifying a particular piece of metering equipment is by using a system of nonrepetitive individual serial numbers. Most manufacturers imprint or etch this information on a thin metal plate, which is then affixed to one of the surfaces of the meter body. Figure 6-3 illustrates the type of information that is found on the meter identification plate.

G-S.1.IDENTIFICATION. - All equipment, except weights and separate parts necessary to the measurement process but not having any metrological effect, shall be clearly and permanently marked for the purposes of identification with the following information:

(a) the name, initials, or trademark of the manufacturer or distributor;

(b) a model designation that positively identifies the pattern or design of the device;

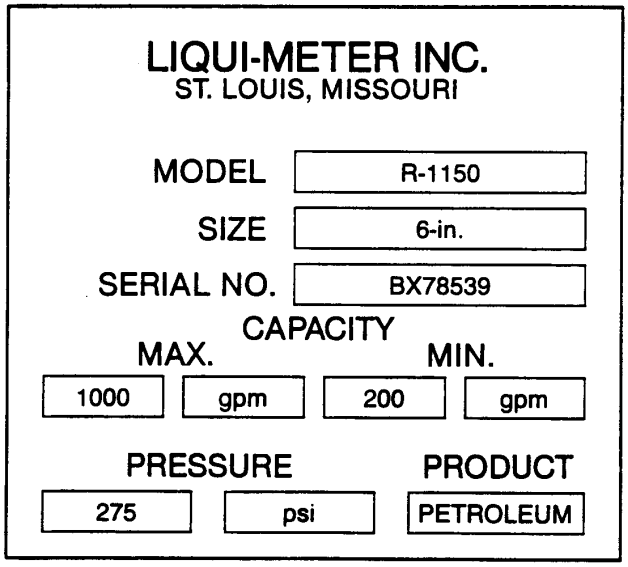
(c) the model deisgnation shall be prefaced by the term “Model,” “Type” or “Pattern.” These terms may be followed by the term “Number” or an abbreviation of that word. The abbreviation for the word “Number” shall, as a minimum, begin with the letter “N” (e.g. No or No.)
[Nonretroactive january 1, 2003]

(d) except for equipment with no moving or electronic component parts, a nonrepetitive serial number;
[Nonretroactive as of January 1, 1968]

(e) the serial number shall be prefaced by words, an abbreviation, or a symbol, that clearly identifies the number as the required serial number; and
[Nonretroactive as of January 1, 1986]

(f) the serial number shall be prefaced by the words "Serial Number" or an abbreviation of that term. Abbreviations for the word "Serial" shall, as a minimum, begin with the letter "S," and abbreviations for the word "Number" shall, as a minimum, begin with the letter "N" (e.g., S/N, SN, Ser. No, and S No.).
[Nonretroactive as of January 1, 2001]

The required information shall be so located that it is readily observable without the necessity of the disassembly of a part requiring the use of any means separate from the device.
(Amended 1985, 1991, and 1999)



General Code, § G-S.1.

In accordance with paragraph G-S.1, identifying information must be permanently marked. This means that it must not be removable or alterable, unless provision is made that removal or alteration will be readily evident. Thus, an identification plate should be attached to a component in some way that prevents its removal without mutilating it: this will prevent the plate from being replaced or transferred to another device. Rivets should be used to attach the plate, not removable screws.

To prevent alteration of the imprinted information, some manufacturers use a plate made of pressure-sensitive material that will clearly show any attempt to erase original markings or alter them in any way. To avoid accidental obliteration of the markings, the operator should make sure that when the device is installed the plate is located on a surface that is visible or readily accessible (as required), but not exposed to frequent abrasion during the course of normal operation.

FIGURE 6-3. Meter identification plate.

The General Code includes one additional requirement that relates directly to marking. This relates to operating controls and other features of the device.

G-S.6. MARKING, OPERATIONAL CONTROLS, INDICATIONS, AND FEATURES. - All operational controls, indications, and features, including switches, lights, displays, push buttons, and other means, shall be clearly and definitely identified. The use of approved pictograms or symbols shall be acceptable. (Nonretroactive as of January 1, 1977.) (Amended 1978, 1995)

General Code, § G-S.6.

In addition to these general marking requirements, several specific marking requirements are included in subsection S.4 of the LMD Code.

S.4.1.LIMITATION ON USE. - The limitations on its use shall be clearly and permanently marked on any device intended to measure accurately only:

(a) products having particular properties; or

(b) under specific installation or operating conditions; or

(c) when used in conjunction with specific accessory equipment.

* * *

S.4.3. WHOLESALE DEVICES.

S.4.3.1. DISCHARGE RATES. - A wholesale device shall be marked to show its designed maximum and minimum discharge rates. However, the minimum discharge rate shall not exceed 20 percent of the maximum discharge rate.
S.4.3.2. TEMPERATURE COMPENSATION. - If a device is equipped with an automatic temperature compensator, the primary indicating elements, shall be clearly and conspicuously marked to show that the volume delivered has been adjusted to the volume at 15 °C (60 /F).

LMD Code, §§ S.4.1., S.4.3.

Limitations of use will be specific to the equipment installed. The internal components of some loading-rack meters are made of materials that are intended for use only with certain products: use with other liquids might damage the components. Such limitations should be marked on the device. For example, the meter might be marked "Not for Use with Solvents."

The meter may also be marked to indicate a specified range of pump discharge rates and/or the maximum working pressure and/or a range of ambient temperatures for which it is designed to operate.

In addition, the meter must be marked to show its maximum and minimum discharge rates. The requirement for the marked minimum discharge rates included in paragraph S.4.2. -- not to exceed 20 percent of the marked maximum discharge rate -- constitutes an additional design requirement (see the section on design requirements

above), and is intended to assure that the system is capable of accurate measurement and registration at relatively low flow rates that may be required for its application and use.

Marked limitations of use and discharge rates will normally be included on the main identification plate located on the meter assembly (see again Figure 6-3), although they may be imprinted on a separate plate.

The required markings for a system equipped with an automatic temperature compensator include "clear and conspicuous" indications on the register, ticket printer (if the system has one), and also on any printed ticket, that the indicated or recorded amount has been corrected to reflect the volume of product at its reference standard temperature (60 ⁄F).

At an early stage in your inspection you should check all required markings and record them, either on the official report form or in your own field notes. Requirements for marking are included in Handbook 44 because the information is often useful, and sometimes critical in determining conformance of the device with other requirements and tolerances. You will need to refer to at least some of this information as your examination proceeds, and should also have it recorded for future reference.

ADDITIONAL INSPECTION PROCEDURES

We have now covered all the items included in the Inspection portion of the EPO for loading-rack metering device. As mentioned at the beginning of the chapter, the EPO outlines what should be considered a minimum inspection. You should become familiar with all the requirements and specifications in Handbook 44, as well as additional requirements in force in your jurisdiction, so that you can conduct a more extensive Inspection when circumstances dictate.

Your instructor will explain to you any additional inspection procedures that are required by your jurisdiction, as well as policies or procedures that differ from those we have discussed in this chapter.

SUMMARY

An official examination of a weighing or measuring device has several components. Examination Procedure Outlines (EPOs), developed by the National Institute for Standards and Technology, provide a systematic and practical framework for conducting field examinations of weighing and measuring devices.

The first component of an examination is Pretest Determinations, which are intended to assure correct application of tolerances and other Test factors.

The second component is the Inspection. The purpose of the Inspection is to determine whether the system being examined conforms with legal specifications and other requirements relating to design, installation, maintenance, and operation. An Inspection should be a systematic procedure for making separate determinations regarding functional components of the system and also for evaluating a number of general requirements and considerations.

The EPO outlines a minimum inspection procedure. The extent of inspection that is appropriate for any given system depends upon the inspector's familiarity with the equipment, the age of the equipment, the existence of complaints, and whether the specific make and model have been evaluated under the National Type Evaluation Program (NTEP). In addition to checking specifications regarding the design, installation, and use of indicating and recording elements, measuring elements, and other components, the inspector also must determine whether required markings are present and readable, whether the equipment is suitable for its commercial application, and whether any aspect of the installation could facilitate fraud.